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Towards identifying mass wasting by change detection in HiRISE images of the north pole of Mars

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Abstract

We are investigating change detection tools for detecting and quantifying changes caused by mass wasting on Mars. The increasing amount of High Resolution Imaging Science Experiment (HiRISE) images has made the detection of fine-scale changes possible, but manual change detection is very time-consuming. Our goal is to support the analysis of surface changes in the north polar region, where mass wasting is very common [1], with automated change detection tools, in order to improve our understanding of dynamic geological processes and related climatic parameters of the planet.

1. Mass Wasting

Since the first time HiRISE captured an avalanche at the north polar steep slopes of Mars in 2008 [2], a much improved temporal coverage of it has been achieved by the HiRISE experiment. This allows for a thorough investigation into change detection which will in turn support the analysis of active geological processes from different perspectives. Russell et al. [3] have demonstrated the occurrence of numerous mass wasting events at one particular scarp over 5 Mars years through image to image comparison. We investigate how this can be achieved over larger areas and in a more automated way.

In one case (Fig. 1) we observed that a “rock” fall seems to have created a relief change along the way carving a linear furrow into the talus deposits at the base of the steep North Polar Layered Deposit (NPLD) scarp and scattering some smaller boulders on the way. The largest boulder involved travelled the longest down-slope and is roughly 4m long × 2m wide × 2m high (through shadow measurements). The coarse fraction of the “rock” fall deposit and the linear furrow show a distinct topographic relief in the image. From the shading pattern of the furrow, the steepness of its inward dipping flanks can be roughly estimated as 10°, which leads to an estimate of about 1m for its depth. Interestingly, the images of the surrounding area seem to show a change at the foot of the NPLD as well.

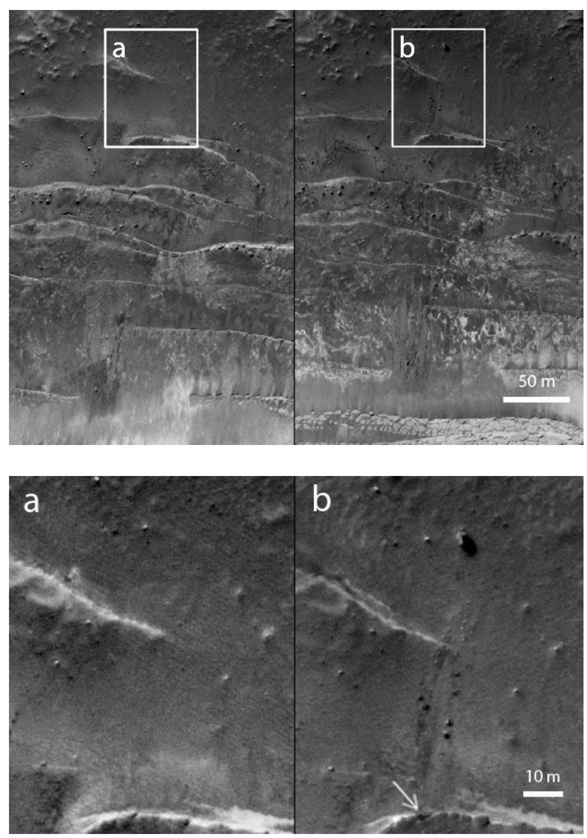

Figure 1: Example of change within 10 days; a boulder has fallen between HiRISE images ESP_016292_2640_RED (left) and ESP_016423_2640_COLOR (right). The boulder is roughly 4m long × 2m wide × 2m high and has fallen from the upslope step coming to rest around 70 m away from its source, which can be seen as a dark gap at the bottom of (b).

This is the most impressive example of mass wasting among many others that were observed between those two images, or between two other images of the same month and area. The effort of detecting such changes could be significantly reduced if a more automated way were to be developed.

2. Change Detection

Wagstaff et al. [4] and Di et al. [5], dealt with this issue, focusing on larger-scale changes, induced by other phenomena (e.g. impact craters, dark slope streaks). Sidiropoulos and Muller [6] attempt a more generalized approach for all kinds of change based on multiple types of images. Observed mass wasting events, such as “rock” falls, however result in very small changes only visible in HiRISE images, and therefore require a process-specific approach with high geometric accuracy.

The fundamental steps of image-based change detection are image selection, accurate image registration, radiometric corrections and the method of change detection itself. A common problem that arises during this process is the detection of trivial changes, such as shadows. In order to avoid this, we are developing a sophisticated system that will reject these and only select the ones which reflect change on the surface of Mars. The image features that can potentially be exploited are various and include modification of scarp edges, new boulders, albedo changes due to new deposits or erosion, and active avalanches.

A further development would be to recognize such changes, which actually occur in three-dimensional space, on HiRISE Digital Terrain Models (DTMs). Detectable height changes are likely associated with new scars in the source area of “rock” falls, new talus deposits, and erosion, as in the example of Fig. 1. Due to the high rate of imaging at the north pole, there are multiple images which comprise stereo pairs and can be used to create ‘before’ and ‘after’ DTMs in order to detect differences in 3D. In the particular case of Fig. 1 for example, there are 25 candidate stereo partners for the first image and 9 candidate stereo partners for the second image. DTM-based mapping of height changes, however, is an extremely challenging task due to the requirements on the resolution and accuracy of co-registration in an area characterised by steep slopes.

3. Summary and Conclusions

Active mass wasting at the north pole of Mars can be studied based on numerous available HiRISE images. This activity is normally associated to many small surface changes. Our goal is to create an automated change detection system for HiRISE images and if possible HiRISE DTMs, to allow for a more rigorous approach to mapping regional changes and quantifying related volumes and erosion rates.

Acknowledgements

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